New Ornithological Radar Technologies for Bird & Bat Discrimination & Species Identification

New Ornithological Radar Technologies for Bird & Bat Discrimination & Species Identification

Mr. T. Adam Kelly, MS, Chief Scientist, DeTect, Inc., Panama City, Florida, USA; Mr. Scott McLaughlin, Senior Radar Engineer, DeTect, Inc., Longmont, Colorado, USA; & Mr. Andreas Smith, Senior Radar Ornithologist, DeTect, Inc., Panama City, Florida, USA

ABSTRACT

Radars are more frequently being used to develop data on bird and bat activity at proposed wind turbine sites for determination of mortality risk. Radar provides superior data compared to traditional bird and bat survey techniques generating highly robust datasets to support the risk analysis. Most radar systems to date, however, have used marine radars and, while some are capable of sizing targets into general classes, they are not able to reliably discriminate birds from bats or insects or provide species identification. Insects can be filtered out of the data using various processing techniques, but the lack of target discrimination between bats and birds makes determination of specific exposure of each problematic. More sophisticated military tracking radars have also been used to track individual birds and bats, and tracking radar data can provide more specific information on wing beat frequency and other characteristics of each target allowing more accurate separation into different size classes for birds and bats, and in some instances, provide identification of specific species. This presentation will review how the bird/bat and species ID data gaps can be addressed using new, advanced radars that will provide much more scientifically sound and detailed data for use in developing bird and bat risk assessments for wind energy projects, airports and other such projects with bird and bat risk issues.

Background

The current state-of-the-art technology for bird and bat risk assessment for wind turbine siting studies uses a dual marine radar configuration that scans in both the vertical and horizontal planes simultaneously. Coupled with advanced, automated, computerized signal processing, these Avian Radar Systems provide vastly superior survey data when compared to traditional field methods. These systems generate highly robust datasets that can be used in developing detailed site activity models and mortality risk assessments.

Figure 1: Typical commercially available avian radar system (DeTect MERLIN 1030e Avian Radar System, 2007 model).

With the exception of foraging raptors, the most likely circumstance for birds to collide with a wind turbine is during periods of reduced visibility. Migrating birds generally see and avoid obstacles even in the dark, but if visibility is reduced by fog, low clouds or other weather phenomena, the ability to detect and avoid an obstacle, such as a wind turbine, is greatly reduced. By contrast, studies of bats at turbine sites show that, even in clear nighttime conditions, bats still collide with wind turbines - the reasons for this behavior is not well understood and continues to be studied.

Most current Avian Radar Systems for bird and bat surveys use off-the-shelf or modified commercial marine radars. Some of the more sophisticated systems (such as DeTect's MERLIN™ system, see Figure 1) are capable of automatically detecting, tracking and sizing biological targets into general classes. The current level of the technology does not provide for definitive discrimination of birds from bats nor identify species. This paper reviews how these “bird-bat” and species data gaps can be addressed using a new generation of advanced Avian Radar Systems equipped with a fixed-beam Vertical Profiler Radar (VPR). The more specific data provided by this technology will provide a more complete understanding of mortality risk and aid in developing improved mitigation strategies at wind turbine sites.

Fixed-beam Vertical Profiling Radars for Wind Turbine Siting Surveys

Over the past two years, detailed radar studies using the current generation MERLIN Avian Radar Systems combined with acoustic bat detectors and thermal cameras have identified specific target characteristics of bats and birds within the radar data. Bats in the vertical scanning radar data were clearly identifiable when in steep, diving flights (consistent with foraging flight behavior), patterns which were markedly different from the horizontal flight trajectories of migratory birds (Figure 2). Bats in horizontal flight however could not be conclusively differentiated from birds in the data and the studies concluded that, while some bat activity can be isolated from vertical scanning radar data, a definitive level will require that additional sensors be incorporated.

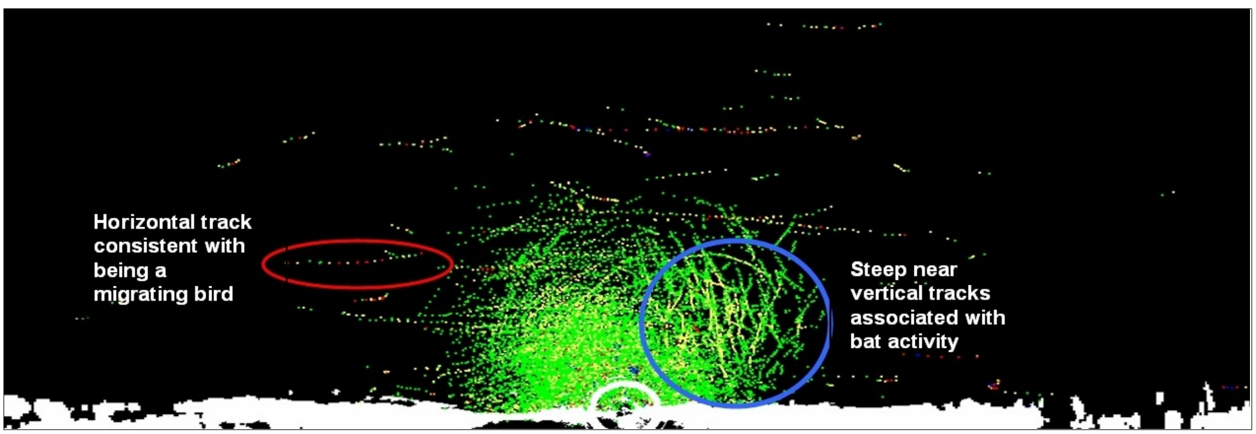


Figure 2: MERLIN Avian Radar TrackPlot of bird and bat tracks.

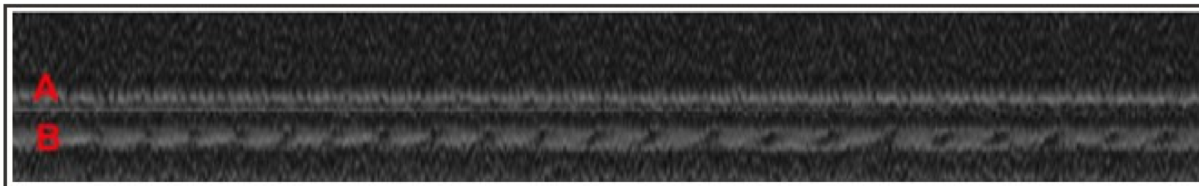
In addition to the marine radars traditionally used for radar ornithology; tracking radars, (such as air traffic and military radars), have also been used to detect and track biological targets. These systems however have not been widely used due to their high cost and operational complexity. Tracking radars though are capable of determining the likely type of biological targets (birds, bats, insects) in the radar beam based on the modulation rate of the radar echo resulting from target's wingbeats. If a single bird is tracked in a radar beam for a period of at least several seconds, then the fluctuations in its echo signature provides a means to obtain the wingbeat frequency (Eastwood, 1967). The fluctuations in reflected energy are related to rapid changes in the circumference and volume of the bird's body (Bruderer, 1997) due to the movements of the muscles during powered flight. Generally the peaks in returned power of radar-tracked birds are related to the wingbeat frequency of the target.

Wingbeat Frequency

Wingbeat frequencies are measured as the number of flapping cycles per second for a phase of continuous flapping. Many small birds intersperse periods of continuous flapping with periods of gliding. From the smallest insects to the largest birds, wingbeat frequency is proportional to the body mass of the animal. Consequently, the smallest targets (insects) generally have the very highest wingbeat frequencies and the largest (birds) the slowest.

Variability in Wingbeat Frequency

Overall there are well established relationships between wingbeat frequency and the body mass of birds, bats or insects. Skilled birdwatchers have long used observations of small differences in wingbeat frequency and wing stroke patterns to distinguish species at distances too great to see other distinguishing details. A particular bird may vary its wingbeat frequency, depending on whether it is taking off, cruising horizontally, climbing or descending. Within the species however these patterns have a relatively narrow range. Birds of similar mass may also have different wing morphology and therefore have a different wingbeat frequency. Short wings are also easier to flap faster than longer wings. Similarly, wingbeat frequency can be used to distinguish bats from birds when the pattern of wings stroke analysis is applied (Figure 3). These wingbeat characteristics can be measured by radar and used to classify bird and bat targets. When combined with sufficiently ground-truthed algorithms, these data may be used operationally to identify certain species and discriminate birds or bats. Additionally, the very high wingbeat frequencies of most insects in flight can be used to discriminate these targets from birds and bats.



The above image shows time on the horizontal axis, range (distance from the radar) on the vertical axis and reflectivity as shades of gray. The reflectivity varies over time as the target beats its wings as it flies through the vertically pointed radar beam. Top line (A) shows the very rapid pulsing of a target passing through the radar beam, this can be strongly contrasted with the much slower pulsing of the lower line (B) which shows one wing beat for every five in recording above (A). Using this method the rapid wingbeat of an insect can be distinguished from a small bird. The fundamental frequency of these recordings will match closely to the size of the target. Micro structure of these recordings is likely to be species specific in many cases and can be identified from a library of ground truthed recordings. Aircraft passing through the beam leave a solid line and don't show the modulation typical of birds, bats and insects (Image below).

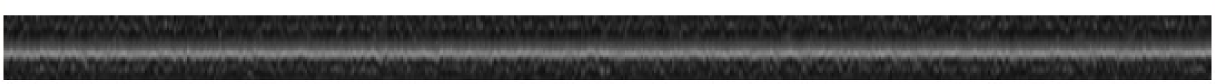


Figure 3: Windbeat Frequency Radar Data

Operational Application of Wingbeat Frequency Data

Figure 4: Prototype MERLIN Fixed-beam Vertical Profiler Radar currently in field testing.

Based on these principles, DeTect is developing a Fixed Vertical Beam Radar based on relatively low cost and highly reliable components with an operational system projected for commercial availability in 2008. Flying targets passing through the beam will have the wingbeat frequency measured - much like the scanning of a product bar code when passed over the register laser at a supermarket. The beam width will be sufficiently wide to allow even large, slow flapping targets to reside in the beam for several seconds allowing for measurement. This new sensor can be operated independently or in concert with an Avian Radar System to provide specific data on the type of target that has been detected, (i.e. bird, bat or insect).

Additionally, the technology will allow inclusion of insect data in the risk model. Current radar survey techniques eliminate insect targets in radar data to prevent overstating bird counts, however, by rejecting insect data rather than classifying it, important data are lost. As an example, for a wind turbine site if insects occur at the highest densities below the rotor-swept height, it is likely that foraging bats would adopt a strategy that would place them below the rotor-swept area. The vertical distribution of insects is likely to have a significant effect on the height distribution of bats and subsequently the probability of a collision with a wind turbine.

Many studies to date have suggested that most large bat kills occur during the fall migratory season. It is important to understand, however, that during migration bats must still actively seek food. A radar that can effectively discriminate birds, bats and insects can provide important information on bat migration relative to insect rich layers in the atmosphere (insects typically stratify into layers in the atmosphere where the temperature is optimal for flight) Insects also can only modulate their flight muscles efficiently in a narrow temperature range: if it is too cold, they must metabolize energy to warm the flight muscles; too warm and they overheat and die. It is possible that bat mortality with respect to wind turbines is highest where these insect layers intersect with the rotor swept zone of the turbine and this technology could be definitive in defining this relationship.

In addition to providing improved risk assessment data, the Fixed Beam Vertical Profiling Radar can also have operational application. For example, it is known that the majority of bat kills occur in a narrow time period in the fall (approximately two weeks). It is also known that a wind turbine with feathered blades kills few, if any, bats. If the technology can establish a correlation between bat distribution and insect activity, then the turbines may need only to be feathered during periods when insects are in the rotor swept height and not for the entire risk period. In this case the Fixed Beam Vertical Profiling Radar could be used as a monitoring and mitigation tool for operating the wind farm. Additionally, a turbine blade that is “smeared” with insect remains may not operate as efficiently as a clean blade. Feathering the blades during heavy insect activity may not only reduce bat strikes, but could increase operational efficiency.

Applying pre-construction survey data to post-construction monitoring will reduce economic losses and dramatically improve environmental compliance.

Conclusion

The Fixed Beam Vertical Profiling Radar technology currently under development is scheduled for field deployment testing in the fall of 2007 and likely will be ready for operational use in 2008. The technology is a breakthrough in the application of radar ornithology technology for wind farm development and management. With ready access to this technology, libraries of wingbeat signatures can be developed and new mitigation strategies devised that minimize both environmental impacts and economic costs to wind farm operators.

References:

Eastwood, E. (1967). Radar Ornithology. London: Methuen

Bruderer, B. (1997). The study of bird migration by radar. The technical basis. Naturwissenschaften 84, 18.